Influence of Small Grain Rotations on Take-All in a Subsequent Wheat Crop

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ABSTRACT

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Wheat (*Triticum aestivum*), barley (*Hordeum vulgare*), triticale (× *Triticosecale*), rye (*Secale cereale*), and oat (*Avena sativa*) rotations were evaluated for their influence on take-all in a subsequent wheat crop. Cultivars of each small grain were planted at two locations for two successive years in plots artificially infested with *Gaeumannomyces graminis* var. *tritici* at the beginning of the study. Wheat was planted in all plots the third year to estimate inoculum potential of the pathogen following each of the small grains. Take-all was severe on wheat following all susceptible small grains (wheat, barley, triticale, and rye). Yield reductions did not differ following susceptible small grains compared with wheat following the resistant small grain oats, with the exception of no significant yield reduction for wheat following wheat compared to wheat following oats at one location. Data indicated that even rye cultivars, which showed no yield losses attributable to take-all, support inoculum of sufficient potential to result in severe disease and significant yield reductions in the subsequent wheat crop.

Take-all, caused by *Gaeumannomyces graminis* (Sacc.) Arx & D. Olivier var. *tritici* J. Walker, is a disease of numerous species in the family Poaceae (9). Research has focused on disease development and yield reductions on wheat (*Triticum aestivum* L.), although barley (*Hordeum vulgare* L.), rye (*Secale cereale* L.), and triticale (× *Triticosecale* Wittmack) also are susceptible (11). Oats (*Avena sativa* L.) are resistant to *G. g. tritici*. Most reports list rye, barley, and wheat in the order of greater susceptibility to *G. g. tritici* (11). Reports of the level of susceptibility of triticale to the pathogen have varied from as susceptible as wheat to intermediate in susceptibility between wheat and rye (3,4,7–9,12).

Research in Georgia using two inoculum levels and two field sites indicated that triticale cultivars were nearly as susceptible as wheat (10). Yield reductions at these sites for wheat, barley, and triticale cultivars were correlated with disease severity (10). Although rye was susceptible, no significant reductions in yield or plant growth parameters were detected (10). Jensen and Jørgensen (4) also demonstrated that yield reductions resulting from take-all for small grains were correlated with the proportion of the root system with symptoms.

In many production areas, several small grains are grown for grain, for forage, or as cover crops. Management practices, such as planting barley instead of wheat in years in which severe take-all is anticipated, have been suggested to limit crop loss until soil suppressiveness is induced (16). However, there is little information on the effect of small grain rotations on take-all severity for subsequent small grain crops. The objective of this study was to quantify the effect of small grain rotations on inoculum potential (the ability of inoculum to cause disease) of *G. g. tritici*.

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MATERIALS AND METHODS

Experimental design. The study was conducted during the 1987–1988 growing season at Griffin, GA, and the 1988–1989 growing season at Byron, GA. The sites and experimental designs have been described previously (10). Both sites used split-plot designs with four replications. The experiment at Griffin had inoculum levels as main plots and small grain cultivars as subplots. The experiment at Byron had small grains as main plots and inoculum levels as subplots. Each main plot was separated by an alley at least 1.8 m wide. Each site was artificially infested with ground oat inoculum of an isolate of *G. g. tritici* isolated from wheat in Georgia. Infestation levels were high

($3.6\ g/m^2$), low ($1.8\ g/m^2$), and none (no inoculum). Inoculum was incorporated with a Rototiller to a depth of approximately 10 cm (10). Neither site had a history of small grain production.

Several cultivars of each small grain were planted in each growing season (Table 1). Some cultivars were replaced after the 1985–1986 growing season because either seed was not available or more adapted cultivars were used. At Byron, additional wheat, barley, rye, and oat cultivars were included. After two successive years of growing the same small grain cultivars in plots, wheat cultivar Stacy was grown in all plots. Tillage operations were limited to disking at Griffin and Rototilling at Byron to minimize interplot spread of inoculum. The plots were planted on 12 November 1987 at Griffin and 23 November 1988 at Byron.

Disease and yield assessment. Fifteen random plant samples were collected, three random 1-m row lengths were counted for tillers and whiteheads, and six random plant heights were measured per plot at decimal growth stage 83 (17) in the same manner as described previously (10). Disease severity was assessed as the percentage of roots with symptoms on a scale of 0–4 where 0 = no symptoms, 1 = lesions on <25% of the roots, 2 = lesions on 25–<50% of the roots, 3 = lesions on 50–<75% of the roots, and 4 = lesions on 75–100% of the roots (13). The weighted mean disease severity was calculated by multiplying the number of root systems in each of the five severity categories by the value of that category and dividing the sum by the total number of tillers examined. The presence of *G. g. tritici* was confirmed by isolating the fungus from selected roots on the selective medium SM-GGT3 (5) and testing the pathogenicity of isolates on several small grains. The center 1.5 × 3.4 m and 1.5 × 4.0 m of plots were harvested on 3 June 1988 at Griffin and 30 May 1989 at Byron, respectively. Grain yield was adjusted to 13% moisture. Thousand-kernel weight was calculated by weighing 200 seed per plot.

Statistics. Statistical analyses were done with the appropriate experimental design by the general linear model procedure with SAS (SAS Institute, Cary, NC). No significant interactions occurred between inoculum levels and cultivars or small grains except where noted, thus, analyses of the main effects were appropriate and complete. After a significant *F* test, a means separation test (LSD) was conducted for each main effect. The Pearson product-moment correlation method was used to determine correlation coefficients.

RESULTS

Take-all was severe at both locations following susceptible small grains based on the disease severity index and percent whiteheads (Table 2). The high and low inoculum levels were not significantly different by the third growing season for any of the parameters measured, therefore, data from these treatments were combined for analyses.

At Griffin, wheat preceded by any of the susceptible small grains had similar levels of take-all as measured by the disease severity index or the percentage of whiteheads (Table 2). At Byron, wheat following triticale, barley, or rye had similar disease severity and percent whiteheads, whereas wheat following wheat had significantly less take-all as measured by these parameters. Wheat preceded by oats had little or negligible take-all.

At Griffin, wheat following oats had significantly greater plant height, tiller counts, thousand-kernel weight, and grain yield than wheat following any of the other small grains (Table 2). Wheat following the other small grains did not differ in these parameters, with the exception of a significantly lower grain yield and tillers per meter for wheat following wheat than for wheat following rye.

At Byron, wheat following oats again had significantly greater plant height, tillers per meter, thousand-kernel weight, and grain yield than wheat following rye, triticale, or barley (Table 2). However, wheat following wheat did not differ from wheat following oats in these parameters. Wheat following triticale, barley, and rye did not differ in tillers per meter, thousand-kernel weight, or grain yield. Wheat following rye had a signifi-

Table 1. Small grain cultivars planted at Griffin and Byron preceding the final winter wheat crop

	Griffin		
Small grain	1985–1986	1986–1987	Byron[z]
Barley	Dawn Volbar	Dawn Volbar	Dawn Volbar Sussex
Oats	Coker 227 Coker 716	Coker 227 Coker 716	Coker 227 Coker 716 Simpson
Rye	Florida 401 Wrens Abruzzi	Florida 401 Wrens Abruzzi	Florida 401 Wrens Abruzzi Pennington Wintergrazer
Triticale	Beagle 82 Councill Morrison Thomas Wytch	Beagle 82 Councill Morrison Thomas Florico	Beagle 82 Councill Morrison Thomas Florico
Wheat	Coker 916 Lincoln Stacy Twain	Coker 916 Florida 302 Stacy Florida 301	Coker 916 Florida 302 Stacy Florida 301 Hunter

[z]The same cultivars were grown in both seasons.

Table 2. Influence of previous small grain on take-all severity and wheat growth and yield

Location	Previous small grain	Disease severity index[y]	Whiteheads (%)	Grain yield (kg/ha)	Plant height (cm)	Tillers/m	Thousand-kernel weight
Griffin	Wheat	3.4 a[z]	30.2 a	2,451 a	81.9 a	37.2 a	34.0 a
	Triticale	3.1 a	27.5 a	2,798 ab	84.4 a	40.9 ab	35.1 a
	Barley	2.8 a	33.7 a	2,881 ab	85.3 a	42.8 ab	35.0 a
	Rye	3.1 a	33.5 a	3,094 b	86.7 a	44.5 b	34.9 a
	Oats	0.4 b	7.2 b	4,559 c	98.3 b	59.0 c	40.9 b
Byron	Wheat	3.0 b	14.9 b	2,570 b	94.3 c	67.7 b	28.3 bc
	Triticale	3.7 a	43.3 a	1,739 a	85.4 b	58.4 a	25.0 a
	Barley	3.5 a	47.7 a	1,789 a	82.1 ab	59.8 a	28.1 ab
	Rye	3.8 a	52.4 a	1,298 a	76.9 a	53.8 a	25.2 a
	Oats	0.1 c	0.0 b	3,061 b	95.1 c	68.7 b	30.8 c

[y]Disease rating scale of 0–4 where 0 = no roots with symptoms and 4 = 75–100% of roots with symptoms.
[z]Means within a column and location followed by the same letter are not significantly different using LSD ($P = 0.05$).

Table 3. Correlation coefficients for estimates of disease and wheat growth parameters

Variables[y]	Correlation coefficients[z]	
	Griffin	Byron
DSI × whiteheads	0.50	0.57
DSI × grain yield	−0.70	−0.68
DSI × plant height	−0.59	−0.51
DSI × tillering	−0.67	−0.43
DSI × kernel weight	−0.78	−0.63
WH × grain yield	−0.56	−0.75
WH × plant height	−0.54	−0.69
WH × tillering	−0.46	−0.54
WH × kernel weight	−0.56	−0.59

[y] DSI = disease severity index; WH = whiteheads.

[z] Correlation coefficients significant at $P = 0.0001$.

cantly lower plant height than wheat following triticale.

Few significant differences were found for wheat following different cultivars of a small grain (*data not shown*). None of these differences were found consistently between sites.

The disease severity index was positively correlated with percent whiteheads at both locations (Table 3). The disease severity index and the percentage of whiteheads were negatively correlated with all plant growth parameters.

DISCUSSION

Take-all and growth of wheat following the five small grains differed from the response expected based on the reported relative susceptibility of the small grains (10). These results agree with those of Garrett (2), who reported that susceptibility, based on root symptoms, of 16 grass species did not reflect the ability of the grass species to perpetuate the pathogen. In this study, all susceptible small grains supported inoculum potential of the pathogen sufficient enough to result in significant levels of disease and reductions in grain yield and plant growth for the subsequent wheat crop. Yield reductions at Griffin of 32, 39, 37, and 46% and at Byron of 58, 43, 42, and 16% (nonsignificant) were found for wheat following rye, triticale, barley, and wheat, respectively, compared with wheat following oats. Kollmorgen et al (6) also reported wheat, barley, and triticale to be effective in the carryover of the take-all fungus compared with fallow or nongraminaceous crops. Similarly, Bockmann (1) reported that rye, wheat, and barley increased disease for the subsequent wheat crop compared with oats, fallow, or nongraminaceous crops. Stetter (15) reported that barley, wheat, and rye were equally effective in maintaining the pathogen for a subsequent spring wheat crop.

The impact of wheat as the previous crop differed between locations. At Griffin, the severity of take-all for wheat following wheat was not significantly different than wheat following the other three susceptible small grains. However, at Byron, the severity of take-all was lower in wheat following wheat than in wheat following the other susceptible small grains, and wheat had similar growth and yield following wheat or oats. This difference may have been a result of severe disease and substantial early season plant death the previous season at Byron where wheat plots had 16 and 7 tillers per meter for low and high inoculum levels of *G. g. tritici*, respectively, compared with 60 tillers per meter for the noninfested plots. Therefore, there was little infested crop residue in these plots to serve as inoculum for the subsequent crop, even though the root tissue examined had severe symptoms.

In contrast, mean tillering for all wheat cultivars at Griffin the second year of the study was 44 and 38 tillers per meter for low and high inoculum, respectively, compared with 63 tillers per meter for the noninfested plots. If soil suppressiveness was involved in lessening disease for wheat following wheat at Byron, this same decrease in disease and increase in plant growth would have been expected in plots at Griffin. In addition, suppressiveness would not have been expected to be expressed after such a short history of small grain production, or, if induced, suppressiveness also might be expected in plots cropped to barley (14).

Wheat following oats also had detectable levels of disease. Results from the two sites suggest spread of inoculum from susceptible small grain plots into oat plots was responsible, rather than a buildup of the pathogen on the oat crop itself. Wheat planted in plots with a history of oat production had a greater amount of take-all at Griffin, where different small grain cultivars were located in adjacent plots. At Byron, where the plot design separated each small grain into main plots, symptoms were rarely observed on wheat roots following oats (Table 2). *G. graminis* was rarely isolated from oats, and in all cases, the isolates were found to be pathogenic on wheat but not oats, indicating the isolates were all *G. g. tritici*.

The role of take-all in reducing wheat growth was indicated by the highly significant negative correlation between the wheat growth parameters and the two disease parameters. No evidence for allelopathic effects for any of the small grains was observed. This was indicated by the lack of differences in plant height or yield for wheat at Griffin following the different small grains in the noninfested plots (*data not shown*). Although noninfested plots were not harvested at Byron, no significant differences were found between plant height or tillers per meter for wheat following rye or oats, the only treatments measured (*data not shown*).

The study indicates that the differences in small grain susceptibility cannot be used for the management of take-all in a subsequent small grain. Oats, which are resistant to *G. g. tritici*, are the only small grain that can be effectively substituted for wheat in cropping systems to manage take-all.

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